

MOISTURE DRIVEN CONVECTION ON JUPITER: A MECHANISM TO
PRODUCE THE EQUATORIAL PLUMES

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The presentation by Stoker is largely contained in a paper to appear in *Icarus*. The abstract of her conference presentation is reproduced here.

Cloud condensation and moist convection processes on Jupiter are examined using an idealized model of a cumulus cloud. A cumulus cloud is represented as a spherical parcel of air which is warmed by latent heat release. Condensation is assumed to occur in the parcel and not in the surrounding environment. The entrainment rate, or the rate at which surrounding air mixes with the parcel, is a free parameter in the model. In the convective lower troposphere, rising air parcels can remain bouyant to high altitudes and reach high vertical velocities. Condensation occurring in deep cloud layers can lift air parcels far enough to produce lifting and condensation of higher cloud layers. The bouyant parcel model is used to demonstrate that moist convection can produce Jupiter's Equatorial Plumes and can account for the vertical distribution of aerosols associated with these features. The Plumes form when ammonia condenses in rising air parcels. The condensation of ammonia clouds does not provide enough bouyancy to produce the vigorous rising motion observed in the Plumes (1982, Hunt et al., Nature 295, 491-494). However, bouyant parcels originating at the water cloud level can lift air up to the ammonia cloud level and higher. The associated rapid transport of hydrogen from a high to low temperature region may be responsible for the observed disequilibrium of the ortho-to-para hydrogen ratio in Jupiter's Equatorial region.

DR. TRAFTON: If we're going to have upward moving elements, then we must have downward moving elements. It's not clear to me that you've accounted for these downward movements of air. Is the problem uncoupled, or how did you account for them?

DR. STOKER: Well, if you're referring to upward moving parcels entraining with downward moving parcels, or mixing with them, I haven't considered that at all. In fact this is a very preliminary model of convective processes and it doesn't get into a lot of the sophistication that's done in terrestrial cloud models.

DR. LUNINE: Am I correct in inferring from your model that if the water abundance determination of Bjoraker is right, then there is not enough water at 4 bars to initiate these moist convective effects?

DR. STOKER: If that model is correct, the moist convection will have no observable consequences on Jupiter. They just won't go.

DR. BJORAKER: They won't do that with ammonia? Suppose that you were to shift your cloud model higher up instead of being 2-4 bars, shift the action up around 500 mb, at the ammonia cloud level.

DR. STOKER: I showed a slide of basically that case. You could do it if you had a 10^{-3} mixing ratio of ammonia, but it's actually ten times smaller than that. It's actually the total energy available from latent heat release that drives moist convection. Unless you have a lot of that energy there you can't do it.

DR. ROSSOW: There's another process which can affect your bouyant parcel since you appear to have done your calculations under the assumption of adiabatic ascent. Of course, these parcels must also explosively produce precipitation which can fall out. I agree that at Mach point-something, vertical motions may well suspend a lot of precipitation, but you had to really assume that the environment was saturated in order to get anything sensible as far as the initial lift in order to get the beast going.

DR. STOKER: Right.

DR. ROSSOW: And that means the environment is probably sitting there and precipitating when you start, so you're not going to get nearly as much lift as you calculated from your adiabatic effect because most water is going to be stripped out by the precipitation. If you did an Earth cloud from that viewpoint, how close to the adiabatic amount would you actually get in an Earth cloud?

DR. STOKER: I haven't done that and I think that it's a good idea. In this model, cloud rises at the pseudo-adiabat which assumes that all condensate falls out immediately. It's an approximation. However, I haven't considered the production of downdrafts by drag of the aerosols that are falling out.

DR. ROSSOW: Let me just say two things about what you're saying. First, that pseudo-adiabat that you are referring to assumes that what falls out is precisely equal to the difference between well-mixed and vapor pressure equilibrium. The whole point of clouds on Earth is that you see two things in ascending cumulonimbus clouds. One is you never see the adiabatic density of cloud mass. You get within a factor of two or three, but you never get that dense. Second, the precipitation mechanism strips more moisture out of the ascent than what you calculate that way. It's not nearly as efficient a system as you're assuming. That doesn't necessarily mean you get no plume, but you might get something less than Mach-whatever updraft velocities.

DR. STOKER: I agree that those vertical velocities are outlandishly high, but this is kind of a theoretical maximum. I have calculated the absolute maximum altitude that ascending parcels can reach assuming solar composition of water.

DR. BELTON: Do you have a reason why they're all so nicely spaced around the planet and why they're all at the same latitude and why they're all at the same state of development?

DR. STOKER: Well, no, but I think Mike Allison could answer that.* Clearly there has to be some kind of forcing that is triggering them in the first place. I'm not really worried about how they get triggered, I only worry about what happens once they do.

DR. BEEBE: There are some observational factors in the Voyager data. During the observational phase, you are taking a consistent movie. If you make strip charts out of an equatorial region, you will see that the translation of velocity in the individual plumes vary. It's not just a trapped wave. They seem to translate in local winds, which would imply that that large annular structure is rotating in the local wind. If it's rotating in the local wind, it's anti-cyclonic, so we expect it to be stable. The site of convection is west of the leading edge of the large plume structure. We also see interaction between convective structures, that are drifting equatorward in the North Equatorial belt, and the plumes. The convection associated with the plumes is not as simple as it looks when you first see it.

DR. WEST: To complicate it even further, one of the methane to continuum image ratios taken by the Voyager 1 camera shows that the northern part of at least one of these plume heads has enhanced methane absorption, which would imply that we're seeing deep down into it. The region immediately north of it is a 5 micron hotspot region which has not had so much enhanced methane, which implies that you're not seeing deep down into that region. How you try to pull all these facts together into a consistent model is... I don't know how to do it.

DR. STOKER: I'd like to respond to one thing that you just said. That is that these are cloud processes and you can't look at one feature and measure one thing on one feature and extrapolate this through all the clouds. The other point is that the Voyager resolution is not good enough to tell you if you have small scale cumulonimbus (that's small-scale compared to very large-scale Earth 1 km cumulonimbus) that is where actual rising motion is occurring. It's only when you get up into the negative shear zone that they form the anvil. In Voyager images, they could appear to be relatively clear and still have patchy clouds that are relatively small in the core region.

*Editor's note: Allison has performed a diagnostic assessment of Jovian equatorial cloud and temperature features in terms of linear wave theory. (cf. 1983, *Bull. Am. Astron. Soc.*, 15, 836.) This work suggests that the plume features might be planetary Rossby waves drifting westward at around 10 m s^{-1} with respect to the mean equatorial flow and latitudinally trapped by the beta effect. It is not clear, however, that he can answer all of Dr. Belton's questions or that the wave interpretation is correct. (See Dr. Beebe's comment following.)